Materials Characterization 144 (2018) 113–119

Contents lists available at ScienceDirect

Materials Characterization

journal homepage: www.elsevier.com/locate/matchar

New surface characterization tools for alumina based refractory material exposed to cavitation - Image analysis and pattern recognition approach

Marija M. Vuksanović[a,*], Maja Gajić-Kvaščev[b], Marina Dojčinović[c], Tatjana Volkov Husović[c], Radmila Jančić Heinemann[c]

[a] The University of Belgrade, Innovation center of Faculty of Technology and Metallurgy, Karnegijeva 4, 11070 Belgrade, Serbia
[b] The University of Belgrade, Vinča Institute of Nuclear Science, P.O. Box 522, 11001 Belgrade, Serbia
[c] The University of Belgrade, Faculty of Technology and Metallurgy, Karnegijeva 4, 11070 Belgrade, Serbia

ARTICLE INFO

Keywords:
Cavitation erosion
Ceramic-matrix composite surface analysis
Erosion testing
Pattern recognition

ABSTRACT

The aim of this study was to examine the influence of cavitation erosion on the morphology of defects formed on the surfaces of alumina-based materials. The alumina-based samples were exposed to cavitation erosion for 42 min. The damages that occurred were monitored at predefined time intervals by measuring the mass loss and observing the sample surfaces. Digital images of surfaces were processed using an image analysis software package to define morphological characteristics of the damages occurred. The calculated morphological parameters were subjected to analysis by pattern recognition techniques to correlate the appearance of particular morphological characteristics with the behavior of the material during cavitation erosion. The newly established method in describing cavitation erosion which uses pattern recognition approach for treatments of morphological parameters calculated for damages by image analysis tools gave the results efficient for material characterization as the traditional one.

1. Introduction

Refractories are mostly considered as materials that are supposed to be subjected to high temperatures and thermal shocks. Therefore, most of the studies of this class of materials are dealing with their synthesis and characterization, which should make them able to undergo severe demands. Protection and properties of their surfaces when subjected to flow of gasses or liquids have been, however, much less studied. Reports on the response of ceramic materials to cavitation, in contrast with the metal ones, appeared much later. Properties and applications of refractory ceramics depend on its structure: phase composition, shape, quantity and distribution of pores and their role related to cavitation has already been observed. Mechanical properties of these materials such as compressive, flexural and tensile strength also depend on particle size distribution of the raw material used, its porosity and other parameters [1].

Cavitation is a process of creation, growth and condensation of bubbles within the liquid [2,3], resulting in surface deterioration and surface mass loss of the material due to generation of vapor inside the liquid flow. Cavitation erosion can occur on the surfaces of metals, nonmetals and refractory ceramics exposed to conditions [4–6]. The standards in cavitation studies set by engineers [7] who studied metals under cavitation were maintained in studies of ceramic materials [8]. The surface properties and the damages formed on the surface were studied using microscopy techniques, but these studies were limited to the description and some elementary measurements mainly oriented towards characterization of the grain size of material [9]. These studies also indicated the importance of investigation of the behavior of ceramic materials under cavitation.

Image analysis developed together with mathematical morphology [10,11] and the application of proposed algorithms became feasible due to the rising power of computers. The descriptive categories in images such as texture, pore shape, grain shape and size, and distances between observed features in the structure could be associated with the parameters defined using measurable characteristics from images [12]. These methodologies were not restricted to one field of science. They were implemented in analysis of not only satellite images but also material microstructure and object shape images, the latter used in biology when dealing with the shapes and structures of animals and plants [13].

According to materials science, powder metallurgy in particular, the morphology of particles dictates their behavior in a multiparticulate

* Corresponding author.
E-mail addresses: mdimitrijevic@tmf.bg.ac.rs (M.M. Vuksanović), gajicm@vin.bg.ac.rs (M. Gajić-Kvaščev), rina@tmf.bg.ac.rs (M. Dojčinović), tatjana@tmf.bg.ac.rs (T.V. Husović), radica@tmf.bg.ac.rs (R.J. Heinemann).

https://doi.org/10.1016/j.matchar.2018.07.003
Received 10 May 2018; Received in revised form 3 July 2018; Accepted 3 July 2018
Available online 06 July 2018
1044-5803/ © 2018 Elsevier Inc. All rights reserved.

system, and it defines many physical and chemical properties dependent on geometry. The pharmaceutical industry, for example, correlates the particle shape factors with tablet formation in terms of easy filling and space compacting [14].

Most of the shape factors for powders were defined from two-dimensional projections of particles obtained by means of microscopy. These parameters were studied and their definition was improved with image analysis procedures included in powerful software packages available nowadays. The image analysis was also used in studies of complex microstructures where the pore characterization was essential [15]. The studies of refractory surfaces under thermal shock were improved by implementation of image analysis [16–20]. The size and shape of the surface damage can give information about the progression of cavitation and can be studied in relation to destruction of the sample. The dynamics of surface degradation was correlated with the mass loss and as shown for metal specimens the cavitation destruction was characterized by the change in size and shape of the surface damage [21,22]. The influence of the surface damage patterns on the behavior of the ceramic material is studied in [23].

In this work, the morphological characteristics of damages were studied by image analysis tools and the data collected in this way were further treated by pattern recognition methods. The aim of this paper was to investigate the possibilities of studying the behavior of the alumina-based ceramic material exposed to cavitation over time by monitoring changes on its surface.

2. Experimental

2.1. Materials

Alumina-based specimens were prepared according to the process developed in Samot, Arandjelovac, Serbia. Raw materials used in this study were chamotte, bauxite and clay, which chemical compositions are given in Table 1.

Components were milled with Al_2O_3 balls in DI water in a polyethylene bottle. The obtained material was pressed in a cylindrical mold (diameter 30 mm and height 9 mm) at 36 MPa. Then, the samples were dried and sintered at 1200 °C for 2 h in air.

2.2. Materials Characterization Methods

2.2.1. Cavitation

Laboratory testing was conducted on an ultrasonic cavitation test setup with stationary specimens according to the procedure described in ASTM G32 Standard [24]. The frequency of vibration and the peak-to-peak displacement amplitude of the horn were 20 ± 0.5 kHz and 50 μm, respectively. The separation distance between the specimens and the horn tip was 0.5 mm. The test was carried out at water flow rates from 5 to 10 ml/s. The temperature of water in the bath was 25 ± 1 °C. Fig. 1 describes the cavitation process in terms of specimen mass loss over time [25]. There are three characteristic periods on the mass loss vs. time curve: incubation, acceleration and steady-state period. During the incubation period, the mass loss is the slowest. Then, it rapidly increases as well as the surface damage area indicating acceleration period. At this stage, erosion is active over the whole surface of the sample. In the stationary period, the erosion rate reaches maximum, a peak on the mass loss vs. time curve [25,26]. In this study the advancement of cavitation was monitored via mass loss measurements and surface damage number, size and shape development.

Table 1
The chemical composition of raw materials used for the preparation of sample.

Components	Bauxite	Chamotte	Clay
	wt%	wt%	wt%
Loss of annealing	14.59	–	7.29
SiO_2	17.72	65.35	60.59
Al_2O_3	60.71	26.67	24.73
TiO_2	2.56	1.40	1.30
Fe_2O_3	3.54	1.58	1.47
CaO	0.28	0.38	0.36
MgO	0.60	1.05	0.98
Na_2O	–	0.60	0.56
K_2O	–	2.96	2.75

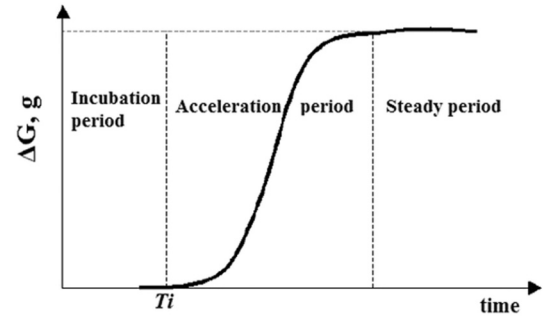

Fig. 1. Mass loss vs. time curve describing cavitation erosion [25].

2.2.2. Image Analysis

The specimen was subjected to cavitation, dried in regular time intervals and its mass measured. After that, high resolution scanned image (600 dpi) of the surface of the specimen was taken. Images of all specimens were taken under the same conditions. Then they were used in a procedure (included in the Image-Pro Plus 6.0, software package, Media Cybernetics, 2006) designed to extract the damaged area from the surface.

The images contained color information that could be analyzed by color separation. This resulted in images with only the level of red, blue and green and they, presented as gray-level images, were used for further processing. This enabled easier separation of damages that cavitation caused on the surface of the specimen. The original image of the sample with blue, green and red channel and separated damages from the original image are shown in Fig. 2. The information obtained from the red channel gave the best separation of the damage on the surface of samples exposed to cavitation. The damage was extracted through the selection of the darkest levels of the image and the obtained objects represented the damages on the surface. The software enabled characterization of each of the objects used for image analysis and calculation the parameters: *Area*, *Aspect ratio*, *Axis* (*major*), *Axis* (*minor*), *Diameter* (*max*), *Diameter* (*min*), *Diameter* (*mean*), *Density* (*max*), *Perimeter*, *Perimeter 2*, *Perimeter 3*, *Roundness*, *Fractal dimension*, *Box width* and *Box height* [20].

The procedure extracts a lot of very small dark spots that in reality do not represent the defect caused by cavitation, so the prefilter options are necessary to exclude extremely small defects eliminating them from further analysis. Another parameter present in a specified range in real damage is the *Fractal dimension*, and only damages that have the *Fractal dimension* in the range 1 to 2 remain in the selection. This is the standard suggested by the software itself. All the specimen images obtained after different exposure times were treated in the same way to maintain the objectivity of selection procedure. The data obtained in this way were analyzed and compared to the data obtained for the mass loss to monitor changes in damage shape and size during the process. This procedure extracted a large number of data from each image that were further analyzed using pattern recognition tools.

2.2.3. Pattern Recognition Approach

A variety of pattern recognition tools have been efficiently applied to describe different processes and to correlate material properties with some processing or structural parameters [20,27–30]. The aim of

Download English Version:

https://daneshyari.com/en/article/7968937

Download Persian Version:

https://daneshyari.com/article/7968937

Daneshyari.com